An Analysis of the Heating Coefficient Concept[1]

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1. Introduction

In a study of the heat balance of natural surfaces, Monteith and Szeicz (1961) developed a new parameter which they called the "heating coefficient." From the formal definition of net radiation and the regression equation,

$$R_N = a(1-\alpha)S + b, \tag{1}$$

relating net radiation R_N and net solar radiation $(1-\alpha)S$, where α is the albedo and a, b constants, they derived a general radiation balance equation,

$$R_N = \left(\frac{1-\alpha}{1+\beta}\right)S + L_0. \tag{2}$$

Here L_0 is the value of R_N when $S=0$ and β is the new parameter, envisaged by Monteith and Szeicz to be indicative of the degree of surface heating induced by unit increase in net irradiation.

In practice (Stanhill *et al.*, 1966), β is calculated as $(1-a)/a$, with the implication that it must be just as good a parameter as is the regression slope a. It is the purpose of this note to demonstrate that such is not the case, and that Eq. (2) is essentially without justification.

2. Data acquisition and analysis

Data for the test of the heating coefficient concept were obtained during June 1962 under the very diurnally uniform climatic conditions of Phoenix, Ariz. Incoming and reflected solar radiation were obtained with upright and inverted solarimeters, net radiation with a modified version of the net radiometer described by Fritschen (1963), and surface temperatures with thermocouples placed 1/2 cm beneath the soil surface under a crop of Sudan grass.

The regressions of R_N on $(1-\alpha)S$, necessary to obtain the slopes a for calculations of β, were fitted statistically by the method of least squares. Resulting correlation coefficients were generally greater than 0.995.

3. Results and discussion

From the plot of β presented in Fig. 1, the greatest single change in this parameter is seen to occur between 19 and 20 June. All meteorological measurements indicated that climatic conditions for these two days were essentially identical, and that the change in β was solely

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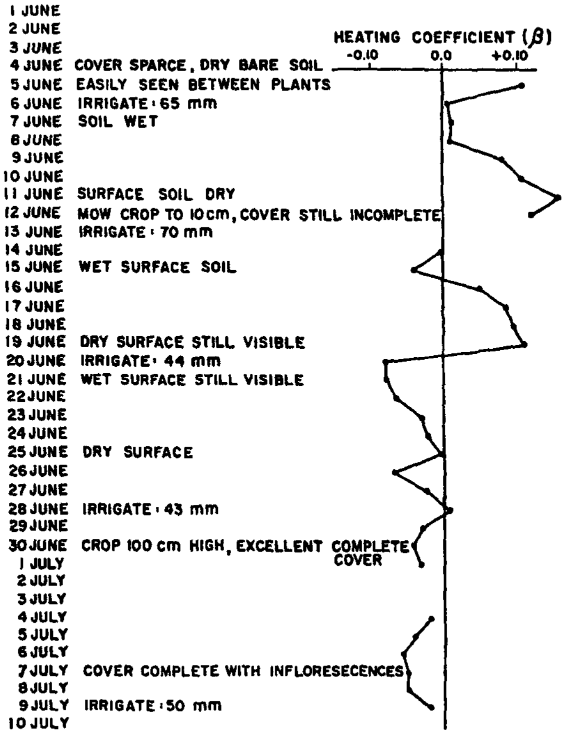

FIG. 1. Variation of the heating coefficient of Sudan grass during four consecutive irrigation cycles at Phoenix, Ariz.

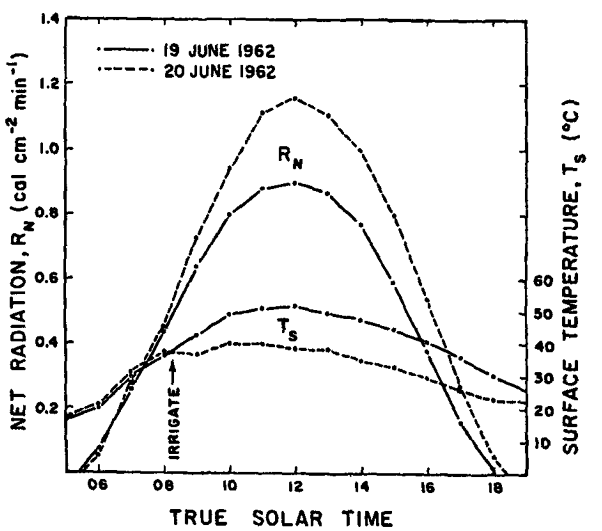

FIG. 2. Diurnal variations of net radiation and surface soil temperature for 19 June (before irrigation) and 20 June (after irrigation).

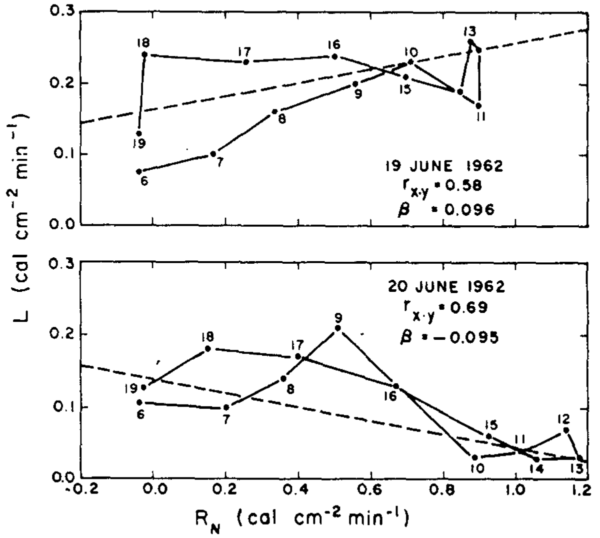

Fig. 3. Linear regressions of net long-wave radiation loss on net radiation for 19 and 20 June and the actual plots of L vs R_N. Numbers by data points give time (MST).

the result of an irrigation applied at 0815 on 20 June. The heating coefficient concept thus predicts that the crop-soil temperature and net radiation of 20 June be out of phase in their diurnal trends to almost exactly the same degree that they were in phase on 19 June. The data of Fig. 2, however, indicate clearly that this did not occur.

The reason for this failure of the heating coefficient concept is that the derivation of Monteith and Szeicz (1961) depends upon the physically unrealistic assumption that net long-wave radiation loss L is a linear function of R_N, i.e.,

$$L=\beta R_N+b/a. \tag{3}$$

Fig. 3 shows that this assumption is poor indeed, regardless of the very high correlation coefficients obtained for Eq. (1) on these days, 0.993 and 0.994, respectively. The fact that L is a small difference between two significantly larger quantities, atmospheric and ground radiation, essentially precludes the possibility that Eq. (3) would ever be very reliable.

In light of these results, it appears that (2) has no advantage over (1); and since Fritschen (1967), in studying net and solar radiation relations over a wide variety of irrigated field crops, found (1) to have no advantage over the more simple equation,

$$R_N=aS+b, \tag{4}$$

it would seem logical to conclude with him that *use of the heating coefficient* and "the inclusion of the reflected solar radiation term does not improve the estimate of net radiation and is not worth the additional effort."

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